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INVENTION DISCLOSURE QUESTIONNAIRE

The questions below will help AirTouch Communications, Inc. and its outside patent attorney determine whether the company should apply for a patent on your invention. Please be as complete as possible.

Return the completed form via E-mail to Greg Caligari or send to:

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Please call Greg Caligari on (415) 658-2075 with any questions.

1. What is the name of the invention?
Network Engineering 2000
2. List the names of all of the inventors.
William C. Y. Lee and David J. Y. Lee
3. List the following dates (if applicable):
 - a. First conceived: [REDACTED]
 - b. First sketched: [REDACTED]
 - c. First constructed: [REDACTED]
 - d. First shown to work: N/A
 - e. First disclosed to third parties: N/A
 - f. First sold to third parties: N/A
4. What problem does your invention solve?
The invention solves the network engineering and operation problems since the mobile locations will be known to the system through location technology. A much better and effective way of doing network engineering and operation can be provided.
5. What "prior art" (existing patents, articles, known concepts) do you know about that relate to your invention? None
6. Who else knows about or has seen the invention (third party, co-workers)?
David R. Lee, David Downes
7. Describe the invention in details, including technical terms. You may attach any notes, drawing, or source code that you think would be helpful.

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WITNESSES

I hereby acknowledge that I have read and understand the information on this form and any attachments to it, and to the best of my knowledge such information and attachments are true and accurate.

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(Signature of Witness)

[Signature]
(Signature of Witness)

David R. Lee
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(Print Name)

Date: [REDACTED]

Date: [REDACTED]

Network Engineering 2000

Description

Location technology has the potential of changing the paradigm of network planning, engineering and operation. With accurate location of mobiles, network can much better understand and track the system performance. This invention presents an intelligent data storage, pattern matching and automatic feedback system that can self train and tune up the system operation engine for a better and effective system engineering based on the data collected and rules developed.

There is another key invention. Combining dynamic power control and dynamic dedicated individualized HPO threshold for each mobile, the network can be much more effectively optimized. This can achieve more than the traditional dynamic channel allocation algorithm in the AMPS as well as the GSM/TDMA system. The key is location. With location of mobiles available to the system, a new horizon can be achieved for system engineering. System can be optimized based on power and HO threshold. These two parameters are the most important parameters for optimizing cellular network.

With location information, many other technologies can be applied more effectively. For example, there are several applications for smart antenna are discussed in this invention.

Benefits

By providing location of mobiles to a intelligent network engineering system, the network performance can be much better operated and optimized. This new algorithm can be applied to all cellular systems (CDMA, TDMA, GSM and AMPS). Subscribers in the network are the most effective system drive testers. By collecting all these data and analyzing them, rules can be developed to apply to instance that happened before. This means a revolutionary way of doing network engineering. This also means that network planning, engineering, operation and optimization can all be done in one step once the intelligent system is developed. This means drastically reducing resources on managing and maintaining the network.

The dynamic power control and dynamic, individualized HO threshold can optimized the system on a per mobile or per data session level. This provides much better granulate than before. Mobile can be optimized individually and that can be directly translated to a most optimized system.

Location also provides the vehicle for system engineer to better engineer the network. Third generation also provides innovated RF mean for engineering smart antenna. With added location information, the smart antenna has the potential to be much more effectively utilized. That means higher capacity and more effective system resource assignment.

In the CDMA system, the SHO region can be controlled by the system. For other system, the where ad when can be decided by the system. Network deployment and engineering will be much easier, capacity will approach its maximum and system quality will at its best. This means the "most optimized" system.

Conclusion

Location technology provides a new avenue for network engineering. It will be cheaper, more effective and better optimized. It is the future for network engineering and we need to be part of it as early as possible. Think about all the headache associated with RF planning, network engineering and operation. Think about all the hassles on conducting drive test day in and day out, in storm or snow. With this innovation, all these work can be drastically reduced or eliminated. It is the future for network engineering and we need to be ahead of the game.

Network Engineering 2000

William C. Y. Lee and David J. Y. Lee
Strategic Technology
AirTouch Communications

Abstract

Introduction of location technology shifts the paradigm of network engineering. It opens the door for providing revolutionary approach for network engineering. Algorithm is discussed in this paper on a revolutionary way of combining parameters made available through location technology and currently available system parameters for future network engineering and operation.

The "continuous" snapshots of the network can be parsed and intelligently stored into the network performance data warehouse as images. These images can be analyzed off-line to select certain "troubled" instances of the network (this can be site specific). These instances can, then, be analyzed through simulation and/or engineer intervention. And optimized solution can be developed. These "troubled" instance and associated solutions can be feedback into the "virtual network engineer" simulated by the AI engine to increase its knowledge base. Later, the intelligent pseudo "network engineer" can identify "trouble" network instance and compare with the existing images and associated solution in the data warehouse. The existing solution then can be applied to perform real time automated network engineering. This is done through image processing by selecting the most similar network instance and associated solution.

By saving more and more "troubled" instances and developed associated solutions, the "virtual network engineer" increase its knowledge bases and becomes more and more "intelligent" and can handle future "troubled" instance based on the "experience".

For example, the dynamic power allocation and individual specific dedicated dynamic SHO thresholds for each mobile can be combined to efficiently engineer the network performance once the mobile location and associated network characteristics can be identified.

1.Introduction

Introduction of E911 location technology opens a new horizon for network engineering and operation. It provides a vehicle for engineer to reach places that can not be reached before and opened a whole suite of options for network engineering and operation optimization. The objective of this proposal is to specify an architecture and algorithm that can be used for better performance and resource management. It uses location technology to optimized cellular network operation and engineering. For example, the smart antenna can be better applied since we know the exact locations of mobile. 3G

supports several different schemes for smart antenna applications, it is possible to have dedicated beam for high speed, high QoS demand individual. Also, HO algorithm can be optimized by combining location information with available data. Before the estimation of where the user is located presents quite a problem since it is quite difficult to pin point the exact location of a mobile through propagation. With E911, each mobile can be accurately located. This provide a better mean for network engineers to analyze and engineer the network more efficiently. Because the availability of mobile location, the following key parameters can now be mapped together. They are location (lat, lon and height), traffic, time of the day, speed and direction of travel. These parameters can be used as input to better engineer the network.

The virtual reality for network can be reproduced and associated optimized solution can be identified by engineering recorded snapshots of the network into data warehouse. Those real life data can be used as inputs to simulator to identify optimized engineering guidelines. Network performance can be analyzed on a per mobile, per site and per system bases.

This is an intelligent and auto feedback based architecture. The “troubled” instances of the network are recorded in the data warehouse effectively through image processing, the optimized solution can be developed later through the recreation of these “troubled” instances. These optimized solutions can be linked to specific “troubled” instance. Later, when the similar “troubled” instance happens, the quick pattern matching engine can identify the “matched” instance in the data warehouse and apply the optimized solution accordingly.

By recording more and more “troubled” instances and develop its associated solutions, the engine becomes more intelligent (the knowledge base increases). The human intervention is heavily needed at the beginning to train the self-learning intelligent engine. Once the knowledge base for the automated engine reaches certain threshold, the human intervention will becomes less and less. It is a safe and effective way to reduce cost and improve network quality.

2. The Algorithm

The advancement of location technology makes it possible for network to identify the location of each mobile with certain accuracy. Consumers are the ideal system performance engineers. By recording the behavior of the system on a continuous bases and seeking better engineering guidelines, the system performance can be better understood and engineered.

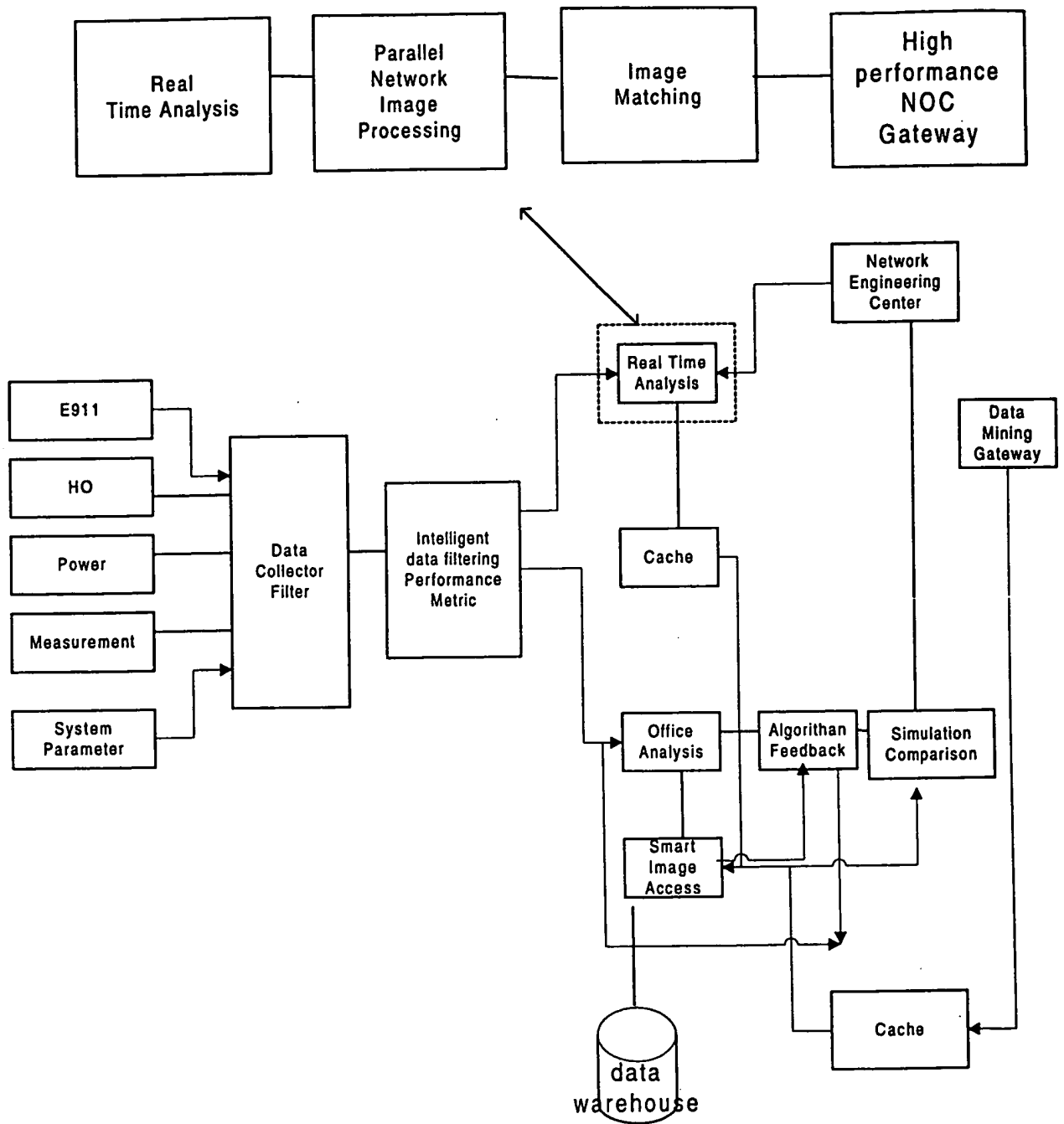


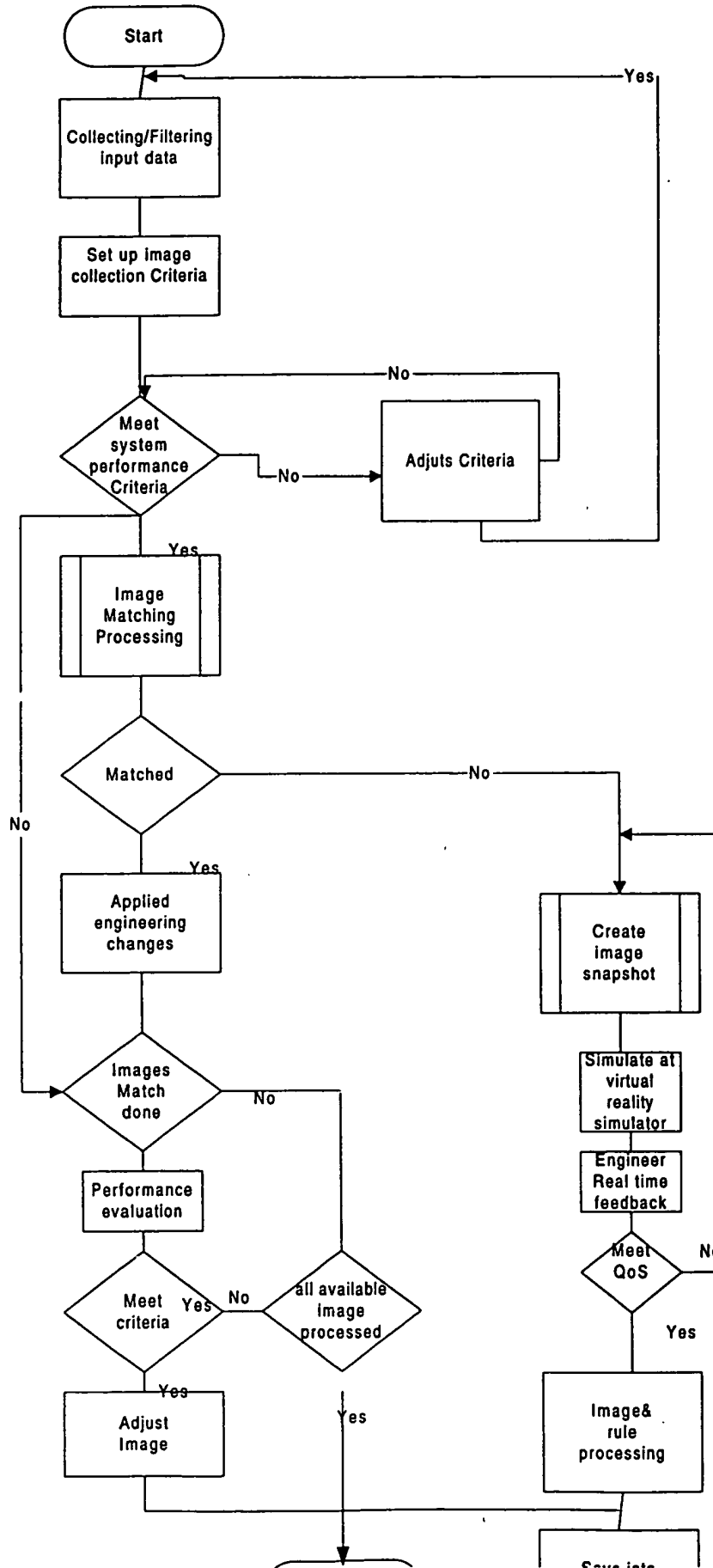
Figure 1. System Block Diagram

The following lists the logical steps for the algorithms:

1. Set up the data bin start collecting snap shots of the system when certain thresholds are triggered.
2. When another set of criteria are reached the intelligent automated engine starts.
3. All snap shots will be saved and set up for virtual reality real time playback.
4. Snap shots can be used as inputs to the virtual reality simulator.
5. With limited human intervention, the optimized solutions for this troubled instance and corresponding solution can be saved to apply later.
6. The "troubled" instance will be saved through image processing algorithm for efficient space and access.
7. This is increasing the knowledge base of the system
8. When a "troubled" situation happens again, the image will be compared with existing "troubled" system images through advanced image matching algorithm.
9. When there is a match within certain percentage then the solution for the matched image can be applied for the solution.
10. Feedback is done by off-line simulation on the know solution to the similar "known" problem.
11. The knowledge base will be populated with more and more instances and the intelligent can be increased gradually.

When specified criteria is met, the instance of the network and subsequent state are recorded in the database. It can be done in two approaches. One is to simulate in real time and provide feedback. The other one is to save in the database then do the simulation off-line then provide feedback.

Power borrowing and dynamic beam shaping can be utilized by intelligently record, process and analyze these snap shots. The feedback loop can be established so that optimized beam forming algorithm can be applied based on the mobile location and speed. A set of site specific optimized algorithms can be developed and automated switch from one to another based on the combination of these system parameters.



Flowchart 1. Algorithm for Network Engineering with Location

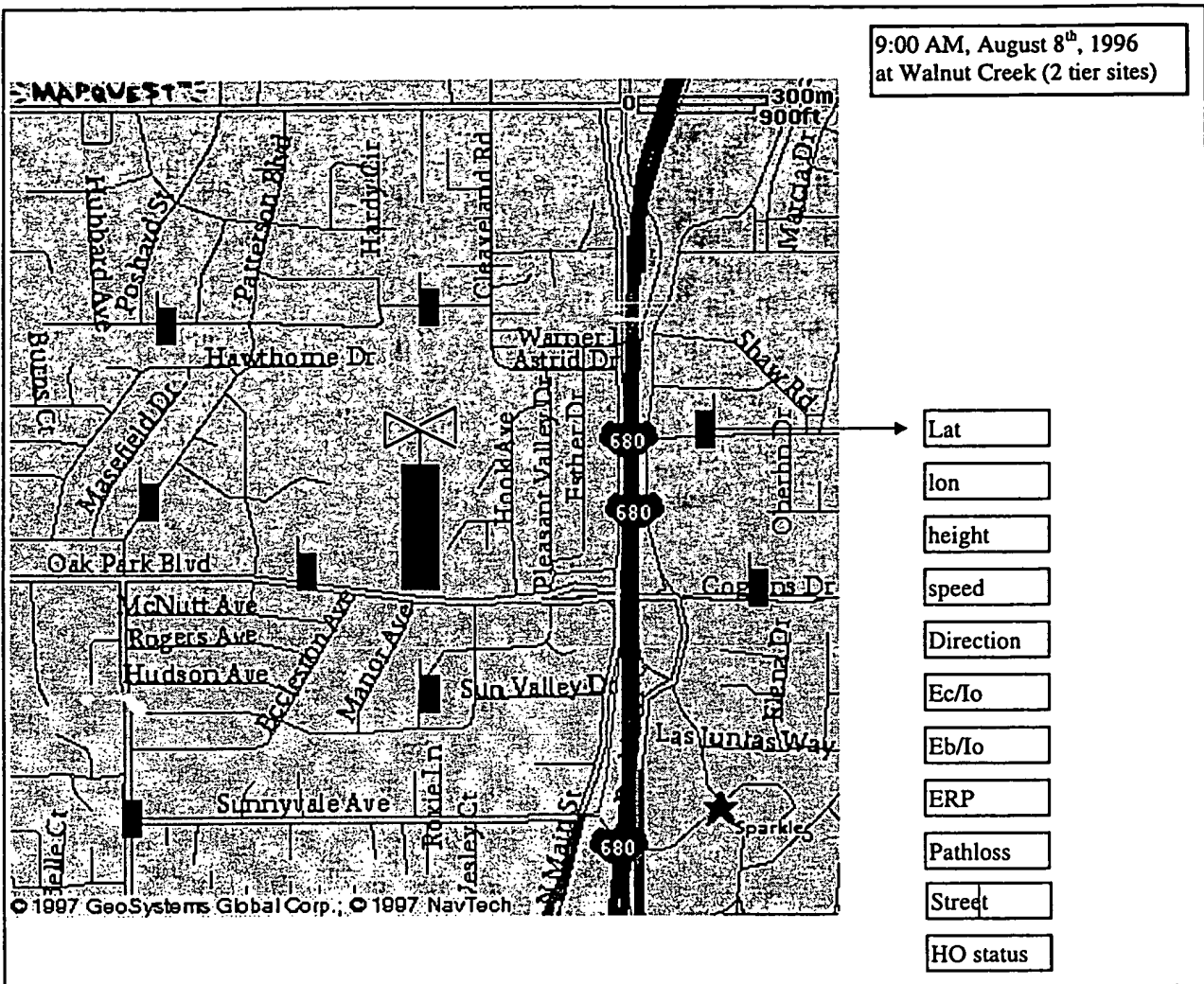


Figure 2. Snap shot of the system

For example, at 8 am, with average traffic speed of 30 miles/hour a combination of 80% data and 20% voice with (X1..n, Y1...n) lats and lons, the beam should be formed at 30 degree direction and 45 degree beamwidth. The lat, lon and associate pathloss implicitly identify the propagation environment. The propagation characteristic based on lat lon with large enough sample categorizes the propagation characteristics. A matrix can be generated with several parameters specified:

Path loss, Eb/No requirement, voice or data, bit rate, moving or station, user behavior, radio environment and time.

With helps of data warehouse and client-server architecture, the engineers can be better equipped to optimize the network.

For example: high data users location, throughput, path loss, delay, power allocation can be identified and used as inputs to, first, further optimize the system and second develop the rule for future system engineering.

E911 presents an opportunity for network operators that they never had before. It is possible to chain many critical network planning data together now. For example, we know where the mobile is going, its direction and speed. This data enables much more intelligent HO and power assignment/control algorithm for network engineering. The data of traffic distribution also provide the input for smart antenna application. The antenna can adjust power and direction based on the traffic distribution at each specific time. The following system phenomenon can be better "controlled" within the system: Power vs. Capacity, Capacity vs. Delay, Stationary vs. Mobile and User distribution.

Data warehousing technique will be used for reliable, real time data access. There are many data associated with each mobile available, access and storage of these data need to be properly executed. Rule based AI can be adopted for fast and intelligently processing of data. The network has the potential to support self-healing and adopt the network demands.

3. Potential Network Engineering Applications

Potential network optimization algorithms are presented and discussed in this Section. Each of them can be part of the optimization element. Third generation adds many dimensions to network engineering and operation. With common, common auxiliary and dedicated auxiliary pilots available for the third generation cellular, the system can be further optimized once the locations of mobiles are available. Based on the QoS that user subscribes and other criteria, better use of system resources can be arranged.

The total transmitted power of the cell site is defined by

$$P_b = P_b (F_{pilot} + F_{sync} + \bar{F}_{paging} + N \cdot \bar{F}_{traffic})$$

where

F_{pilot} is the power allocated to the pilot channel (a fixed value)

F_{sync} is the power allocated to the sync channel (a fixed value)

$\bar{F}_{paging} = v_p \cdot F_{paging}$ is the average power allocated to the paging channel

v_p is the paging channel activity factor (percentage of time transmitting at full power)

$\bar{F}_{traffic}$ is the average power allocation to the traffic channel. The power of this channel will fluctuate due to power control.

Solving for N, the number of simultaneous users supported is

$$N = \frac{(1 - F_{pilot} - F_{sync} - \bar{F}_{paging})}{\bar{F}_{traffic}}$$

Once the power allocations to each channel type are known, the total capacity can easily be determined. To determine power allocations for each channel type, the standard link equation to solve is

$$\frac{E_c}{I_t} = \frac{F_{pilot} P_b G_b G_m L_p}{N_f kTW + I_o W + I_{oc} W}; \quad \text{Pilot channel}$$

$$\frac{E_b}{N_t} = \frac{F_{ch} P_b G_b G_m L_p P_g}{N_f kTW + I_o W \alpha (1 - F_{ch}) + I_{oc} W}; \quad \text{All other channels}$$

where,

P_g = Full rate processing gain (9600 bps - 21 dB) for channels other than pilot

P_b = Basestation total output power

F_{ch} = Fractional power allocated to a channel (without activity averaging)

G_b = Basestation antenna gain plus any loss between the antenna and low noise amplifier (10 dB typical)

G_m = Mobile antenna gain plus any loss between the antenna and power amplifier (0 dB typical)

L_p = Mean path loss including fading and penetration losses

N_f = Forward link system noise figure (8 dB)

I_o = Intracell interference

I_{oc} = Inter-cell interference

α = Orthogonality (0=Orthogonal, 1=non-orthogonal for pilot channel)

W = Spread bandwidth (1.23 MHz)

K = Boltzmann's constant

T = 290 Kelvin

If we define a frequency reuse factor as

$$F_f = \frac{I_o}{I_{oc} + I_o}; (0.3-1.0)$$

and the same cell interference is defined as

$$I_o W = P_b L_p G_b G_m$$

substituting

$$\frac{E_c}{I_t} = \frac{F_{pilot} P_b G_b G_m L_p}{N_f kTW + P_b G_b G_m L_p \frac{1}{F_f}}; \text{ Pilot channel}$$

$$\frac{E_b}{N_t} = \frac{F_{ch} P_b G_b G_m L_p P_g}{N_f kTW + P_b G_b G_m L_p \left(\alpha(1 - F_{ch}) + \frac{1}{F_f} - 1 \right)}; \text{ All other channels}$$

3.1 Dynamic Power Allocation

Two enhanced concepts are introduced here. The first one is the dynamic power allocation. The other one is the concept of tailored HO threshold for each individual mobile. Power within a specific site as well as the whole system can be dynamically allocated to achieve the best performance of the system. Before E911, power optimization is very difficult because some of the parameters are missing to perform a deterministic analysis on the system. With location technology, more data are available and more intelligent algorithm can be applied to optimize the system capacity. Power adjustment in CDMA system is equivalent to channel assignment of GSM or TDMA system. With a better picture of the system through location technology, the power can be more effectively and dynamically assigned. The dynamic power allocation of a CDMA system is equivalent to dynamic channel allocation of TDMA, AMPS and GSM system. However, many orders of accuracy can be achieved by leveraging location information.

With speed and direction of travel available through location information, the system loading and other characteristics can be accessed more accurately than before. The ETAK data can be combined with the location, direction and speed of travel to identify which road the mobile is actually on and to predict the behavior of mobile. Power, hence, can be effectively dynamically assigned to each sectors or mobile.

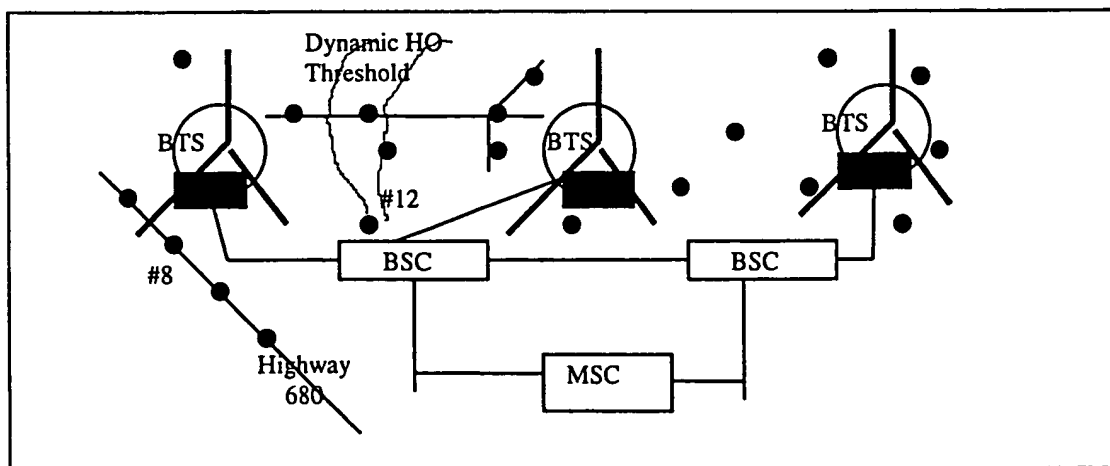


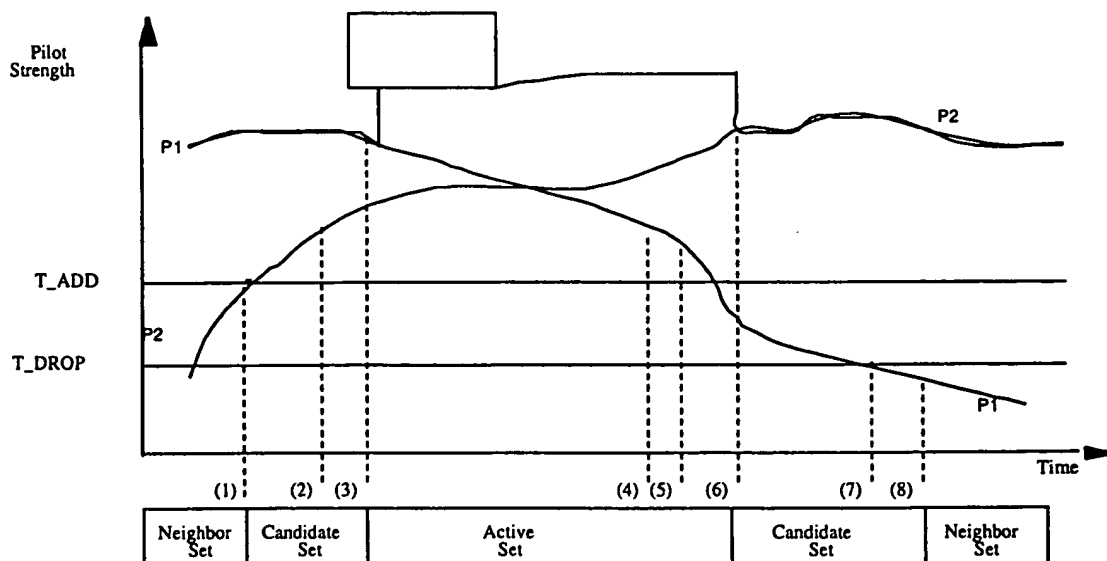
Figure 3. Dynamic Power Allocation

Instant calculates and estimates required power for each mobile can be done in a real time base. This is based on the speed, direction and environmental characteristic (for example, mobile # 8 might be on highway 680 and is traveling at 60 miles/hour, mobile # 12 will go through a big shadow in the next 12 ms for BTS 1) is the key to the algorithm. The system resources are accessed and allocated on a dynamic base. It is also critical to take the advantages of the cell breathing feature in CDMA system to ensure that enough power and load are shared among all sectors.

3.2 Dynamic Dedicated HO Threshold for Individual Mobile

Again, with available directly and indirectly data through location, each mobile can have its own HO threshold based on the system resource, capacity and each subscriber's demand. This approach will definitely better using the system resource, control interference and provides tailored customer services.

Before only HO area can be defined and leveraged since the system dose not know exactly where the mobile is, its associated RF characteristics and how much resource it needs. With location technology, the system will not only know where the mobile is but also how much resource and potential impact to the system from each mobile. Tailored and individualized HO threshold can be applied to effectively control each mobile and thus optimize the system.



Courtesy Qualcomm, Inc.

Figure 4. HO Overview

With dynamic dedicated SHO threshold, system can control where, when and by whom the mobile should be served in the system. This algorithm provides how the mobile can interact with the other three critical parameters (where, when and by who) at each instance and location of the system.

Mobile with no need for SHO can be transferred between cells very quickly by setting the SHO threshold to be very small. Mobile needs to be off load to other less busy cell can also be achieved through the dynamic dedicated HO threshold.

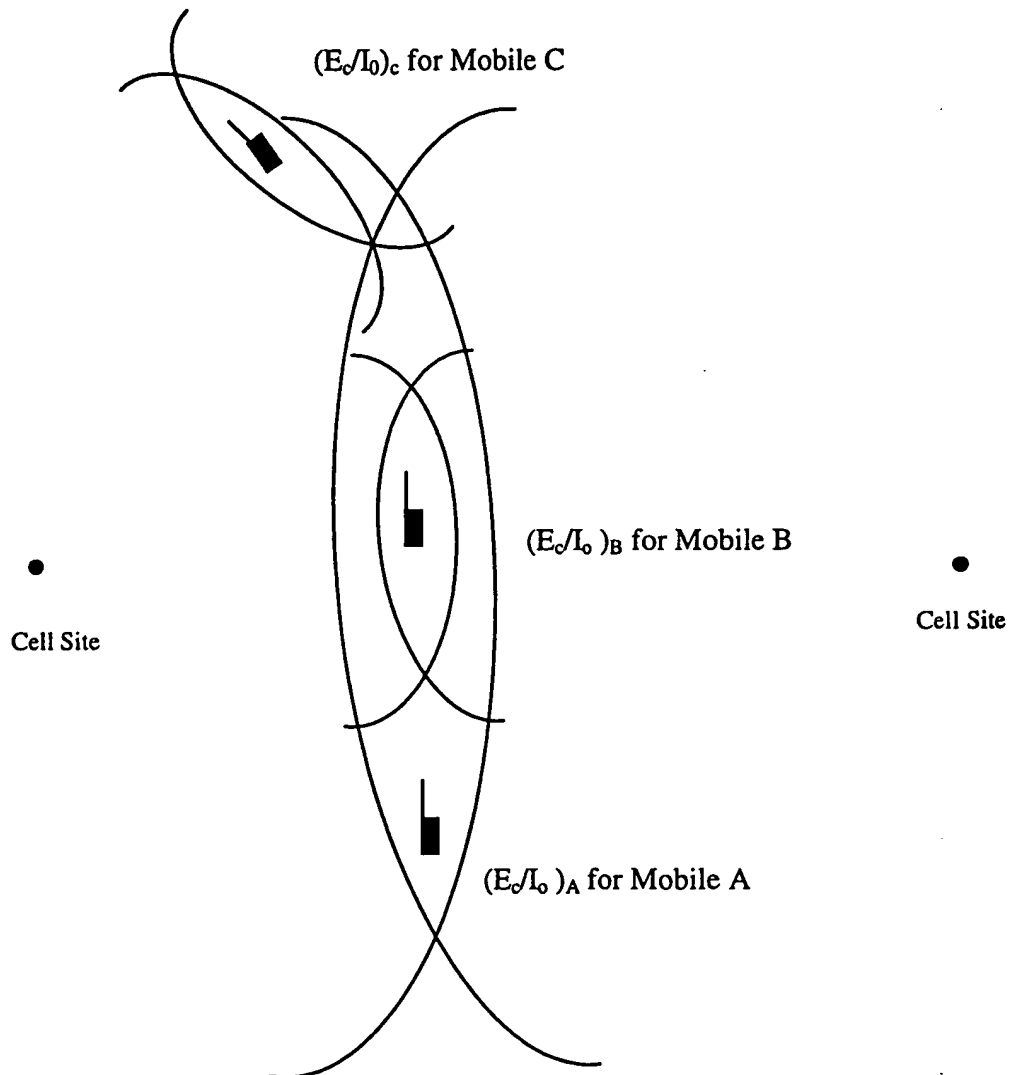


Figure 5. Example of SHO Region with Dynamic Dedicated HO Threshold

As shown in the above diagram, mobile A should be HO to BTS 2 very quickly since BTS 2 can provide high quality from that demarcation point and there is no need to

occupy resource from two BTSs. However, mobile B is traveling through an area that really needs SHO gain to maintain good quality voice service. The HO threshold for mobile B can be personalized to secure attention from both BTS 1 and 2.

By combining dynamic power allocation with individualized dynamic dedicated HO threshold, opened up many effective way of controlling the SHO region which is directly related to the system resources and tailored for each mobile.

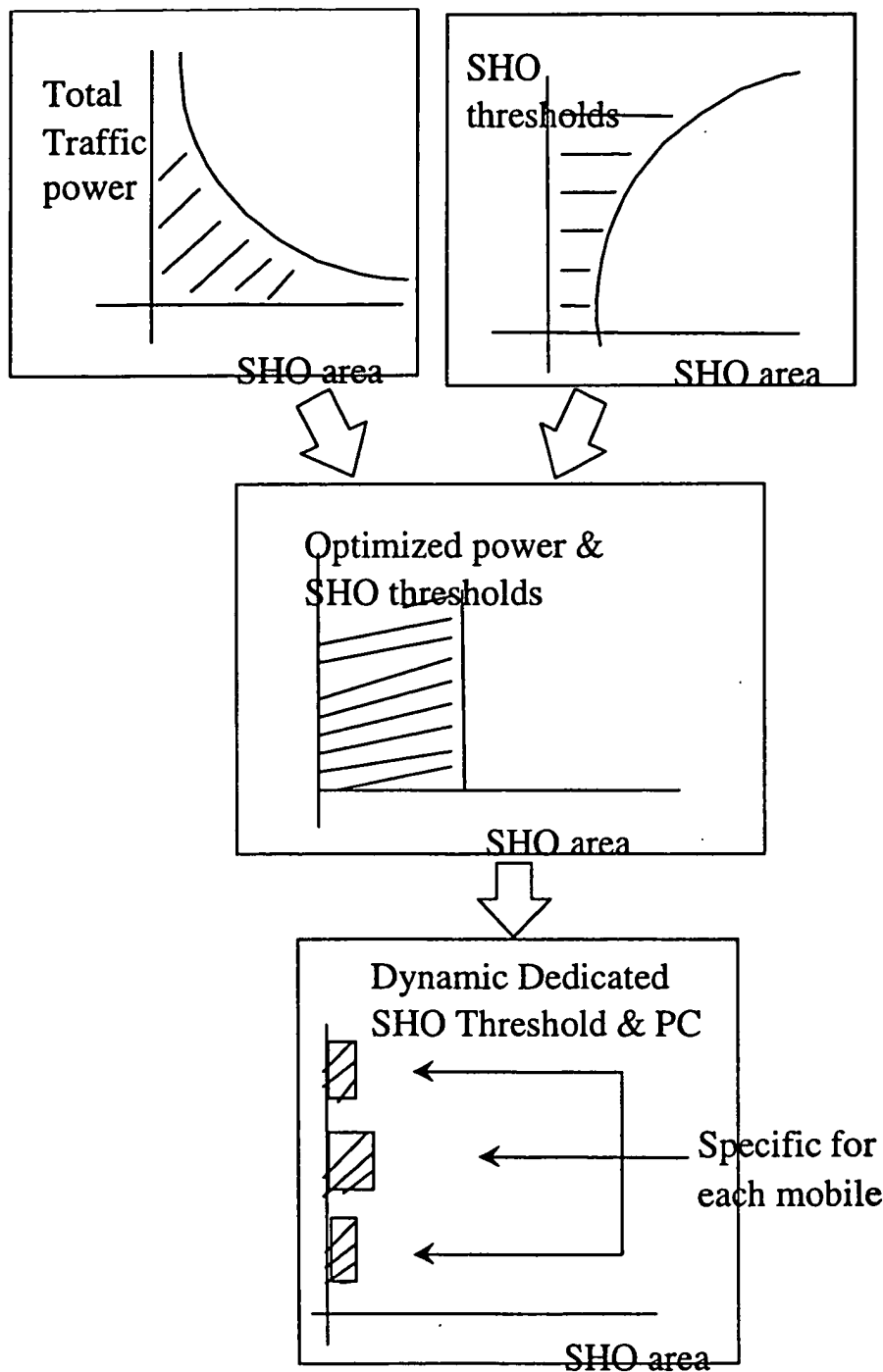


Figure 6. The HO Threshold for Each Mobile is Ultimately Optimized

3.3 Time and Location Based HO for Individual Mobile

For systems using hard HO, mobile can be Hoed based on its location, its timing, system capacity and interference level. The system can collected enough measured data from these free drive test engineers (customers) to make intelligent optimized decision at a specific time and location. Better yet, this HO threshold can be tailored to fit each mobile with optimizing system capacity and interference in mind. This new algorithm can reduce drastically ping pong HO, avoid too early HO, can perform capacity sharing and reduce interference.

3.4 Dedicated Beam for Specific Mobile

For example, dynamic dedicated smart antenna can assign power in the direction of a high speed data user U_H or group of users, thus limiting interference to all other users. It can steer the beam and adjust the power more intelligently since the location, speed and direction information are available now and can be used to better balance the system resource and performance.

Since the mobile location is available, the best direction for shooting energy can also be identified. The location and propagation characteristics can be better correlated. Sometimes, they are not shooting at the right direction without location technology.

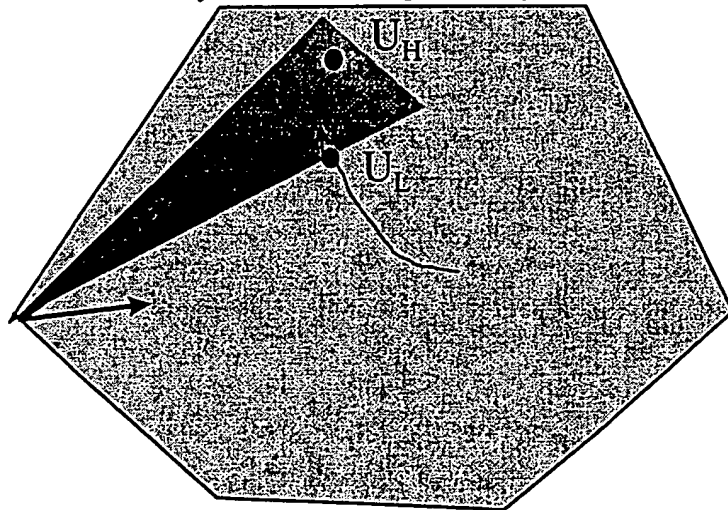


Figure 7. Steering Beam based on Mobile Location

3.4 Dedicated Beam Within Sector

Dedicated wider beam can also be arranged to service specific group of mobiles within a sector that are demanding high throughput or experience quality problem. The interference will be limited within the dedicated beam without impact of the performance of the serving sector and other overlapped coverage areas from other sectors to limit chain reaction.

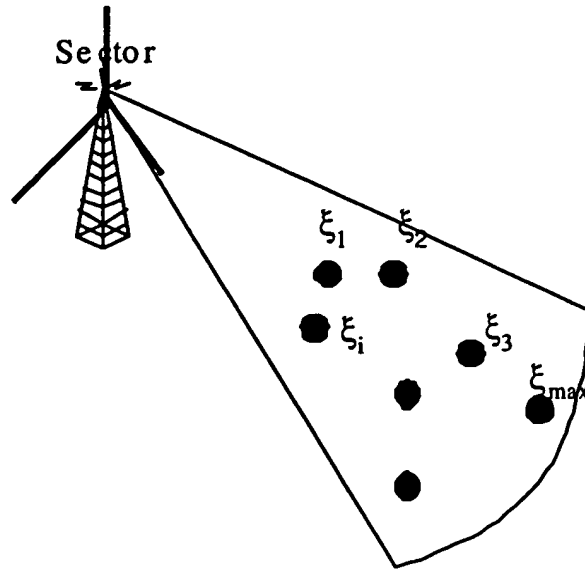


Figure 8. Dedicated Beam for Specific Sector

3.6 Propagation Model

The most accurate propagation model is inherit in the E911 technology. Propagation data can be derived from the users so that the propagation characteristics at each "bin" in the system are fairly accurately accessed and can be used as the input to network engineering. These database needs to have a feedback mechanism so that the system performance can be updated on real time base.

4. Pros and Cons

E911 provides brand new dimensions for network engineering and capacity simulations. The most effective, system wide drive test is conducted continuously by the network customers. By leveraging and process these information intelligently, network engineering process can be revolutionized for better quality and lees cost. Besides that, with location information, the system resources can also be much more effectively controlled and customer needs can better tailored on an individual basis.

5. Conclusion

Location technology will revolutionize the way we perform network engineering and operation. With several direct and indirect extra network engineering parameters that can be derived through the location technology, the network engineering and operation have high possibility to be much better optimized, managed with less cost.

The rules of the game have changed fundamentally because of location technology and we need to be ready or be ahead.